EFFECTS OF FOCUS FILM DISTANCE (FFD) VARIATION ON ENTRANCE TESTICULAR DOSE IN LUMBAR-PELVIC RADIOGRAPHY

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Abstract:
Introduction: With the steady increase in public and professional concern regarding the biological effects of ionising radiation, there is a need for both the Chiropractic and Radiography professions to improve imaging techniques for the lowering of patient radiation doses. Lumbar radiographs are essential in chiropractic general practice for biomechanical diagnosis and postural analysis. Detailed anatomical measurements are taken from spinal radiographs for the determination of various biomechanical alterations for clinical purposes. The quality of spinal radiograph is dependent on a number of factors, including Focus Film Distance (FFD), magnification ratios, penumbra, contrast and density. Variation in FFD will vary magnification factor (MF) and Penumbra.

Objectives: The study aims to investigate the relationship between FFD and received radiation dose to patients, where the radiation dose to the testes may be significantly lowered whilst still maintaining acceptable image quality. Methods: Radiographic images and dosimetry were obtained with a Seimans wall-mounted X-ray unit. All anterior/posterior (AP) and lateral lumbar-pelvic radiographs were taken of an anthromorphological phantom that resembles human tissues, at both 100cm and 200cm FFD. Five central beam air doses were measured for all parameters to demonstrate patient entrance doses.

Results: For AP lumbar-pelvic radiography, increasing FFD by a factor of two resulted in an approximately 30% decrease in entrance dose to the testes. For lateral lumbar-pelvic radiography a two fold increase in FFD resulted in a 70% reduction in entrance dose.

Conclusions: The study suggests for the first time that an FFD of 200 cm, which is largely utilised by the chiropractic profession, is an efficient method of minimising radiation dose to patient, during lumbar radiography.

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INTRODUCTION

Lumbar radiographs are essential in chiropractic general practice for biomechanical diagnosis and postural analysis. This clinical tool is utilised for the detection of degenerative processes, screening for anomalies and contraindications to spinal manipulative therapies. Detailed anatomical measurements are taken from radiographs for the determination of leg length inequality, pelvic tilt, pelvic rotation, sacral base angle, and intervertebral disc height(1).

Radiographic quality is dependent on a number of factors, including focus film distance (FFD) (distance between the anode and the xray film), magnification ratios, penumbra, contrast and density. Variation in FFD will vary magnification factor (MF) where MF is defined by:

$$MF = \frac{\text{Image Size}}{\text{Object Size}} = \frac{FFD}{FOD}$$

MF can be easily calculated from the ratio of FFD to Focal Object Distance (FOD):

Penumbra is the blurred area of geometric unsharpness at the edges of the film image. There are two factors that can alter penumbra: FFD and focal spot size of the x-ray source(7,8). An increase in FFD will decrease the angle of divergence of photons reaching the film thus reducing penumbra. An increase in collimation will also reduce secondary or scatter radiation which is deleterious to image quality. The advantage of minimising penumbra is that it optimises image resolution and affords greater accuracy upon diagnostic measurement. It is therefore an important consideration for spinographic analysis.

The selection of longer FFDs during spinal radiography will have the following influence:

a) Reduction of magnification error &
b) Superior image resolution by the reduction of penumbra (edge blur).

There is an ongoing debate about FFD selection within both the chiropractic and radiographic professions. A common practice by chiropractors is to use an FFD of

180-200 cm for erect spinal radiography. Diagnostic radiographers generally use an FFD of 100-120 cm. This is because radiographic spinal imaging is frequently done supine and the equipment has limited vertical tube movement. Potter-bucky grid specifications are often set at an FFD of 110cm which restricts the use of longer FFDs (due to grid cut-off effects that can occur on the edges of the radiographic image).

While increased image resolution is readily accepted as providing more accurate measurement analysis(2), little information exists as to the subsequent reduction in patient entrance doses when employing larger FFDs. Controversy exists, suggesting that there is the risk of increased radiation dose to the patient with increased FFD(7,8) due to the nessessary alterations in kVp and mAs. Aitkenhead et al (3) studied radiation reducing methods in scoliotic patients by modifying FFD, patient positioning and filtration. Their finding suggest that a variation in FFD from 72 to 84 inches (183 cm to 213.5 cms) had little effect upon organ dosage. However, Taylor(4) has stated that longer FFDs are preferred as they decrease both radiographic distortion and absorbed dose to the patient.

Increasing FFD with a constant kilovoltage peak (kVp) will decrease the subsequent X-ray intensity, the radiographer/chiropractor must therfore increase the exposures time, measured in milliampere seconds (mAs), to maintain optical density for the resultant image. This increase in exposure time would otherwise cause the patient to be exposed to an increased level of ionising radiation(5). However, at a longer FFD the lower energy radiation component "30-50 kVp" is absorbed by the air gap prior to incidence on the patient, that is there is a hardening of the x-ray beam.

This paper proposes that this beam hardening effect counteracts the increase in exposure, measured with respect to entrance testicular doses, incurred during long distance lumbar-pelvic imaging. Fickel(6) has shown that bone marrow, uterus and gonads are subject to the largest doses during lumbar radiography. For this reason and for the peripheral nature of the male gonads, testes have been chosen as the critical organ for the investigation of patient dose during lumbar-pelvic radiography. The study aims to investigate the relationship between FFD and received radiation dose to patient and will demonstrate that by manipulating FFDs, the radiation dose to the testes may be significantly lowered whilst still maintaining acceptable image quality.

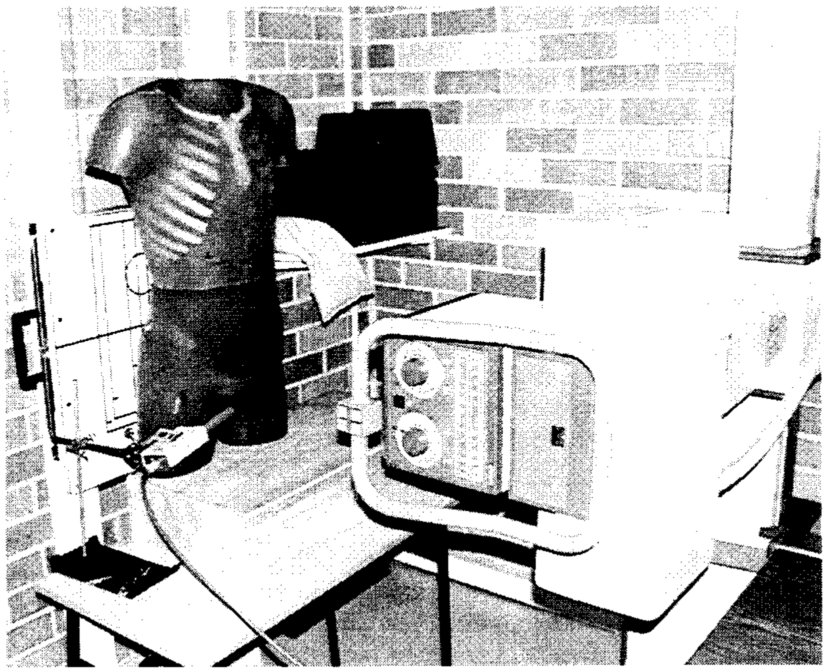
METHODS

i) Radiographic techniques

Radiographic images and dosimetry were obtained with a Seimans wall-mounted X-ray unit (3 phase). An oscillating grid of ratio 13:1, 60 lines/cm, and focal length of 110cm was employed for all radiography.

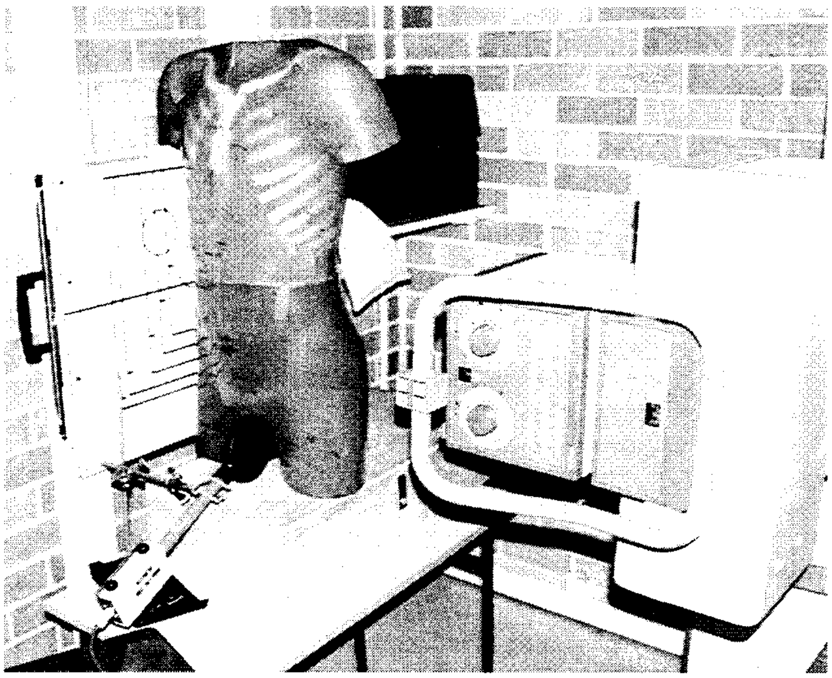
Erect anterior/posterior (AP) and lateral lumbar-pelvic radiographs were taken of an anthromorphological phantom that resembles human tissues, at FFD's of 100 cm and 200 cm (figure 1). Standard positioning techniques were employed. The AP lumbar-pelvic projection demonstrated from L1 to the upper third of femurs vertically and laterally to include all pelvic bones. Collimation was carefully restricted to the skin lines of the morphological phantom for all data collection (figures 1 & 2).

Figure 1. Photograph representing an anthromorphological phantom positioned for an anterior to posterior view. Note the positioning of the ion chamber densimeter anterior to the testes (arrow).



The lateral projection demonstrated from the 12th thoracic vertebra (T12) to the coccyx vertically and to the skin line of the phantom antero-posteriorly. Positioning was performed so as to ensure that no anatomical rotation occurred for the projections (figures 3 & 4). For both projections, 35 x 43 cm MR4 type Agfa film with an MR800 screen combinations were used in conjunction with an Agfa-Gaevert Daylight Processing system.

Figure 2. Photograph representing an anthromorphological phantom positioned for a lateral view. Note the positioning of the ion chamber densimeter anterior to the testes (arrow).



At both 100 cm and 200 cm FFDs, AP lumbar-pelvic collimation was maintained so that the testes were within the primary beam. The lateral collimation however, excluded testes from primary beam in accordance with chiropractic X-ray technique and received only scatter radiation.

ii) Densitometry Comparisons

The AP and lateral images were standardised for optical density using a densitometer (X-Rite 501). It was necessary to modify radiographic factors to maintain acceptable diagnostic quality and consistency of optical density. The kVp was kept constant and the mAs was increased according to the inverse square law. Five densitometry readings were taken and averaged for a specific anatomical reference point on the 100 cm and 200 cm FFD radiographs.

Anatomical reference points were chosen for similar areas of density. For the AP radiographs the right inferior articular facet of 5th lumbar vertebra was chosen for comparisons of optical density. For lateral radiographs the anterior superior body of the first sacral segment was used as a reference point. The average densitometer readings are as presented in Table 1.

iii) Dosimetric techniques

Once comparable optical densities were achieved for FFD variation, entrance testicular doses were obtained using ion chamber dosimeters (MdH 2025 Series Radiation Monitors). All dosimeters used in the study were calibrated against a national reference dosimeter, thus no relative error calculations were required for the reference factory calibrated ion chambers.

A 3 centimeter squared (cc) dosimeter was used for AP lumbar-pelvic radiography so as to obtain primary radiation readings. The dosimeter was placed securely at the level of the inferior pubic angle and five readings obtained.

A 180cc dosimeter (paddle) was used for lateral lumbar-pelvic radiography for scatter radiation readings at testicular level. The dosimeter paddle was placed between the thighs as high as the phantom allowed. Some radiation shielding occurred due to thigh tissue overlying the testes. This replicates the normal human anatomy. Five readings were obtained and averaged.

Five central beam air doses were measured for all parameters to demonstrate patient entrance doses for a homogenous beam. Consistency in laboratory conditions were considered to be paramount during the data collection, the following parameters were kept constant:

a) Room temperature: 21.2o C to 22.7o C
b) Air pressure: P = 1025 mBar (102.5kPa)
c) Processing factors: i.e. image development time, temperature and chemical replenishment rates were kept constant.

RESULTS

AP and lateral lumbar pelvic X-rays were performed on the phantom and densitometry recordings were made at both 100cm and 200cm FFDs. All data is presented as an average of five readings of each view and FFD (table 1). Note that optical density decreases in both AP and lateral views of 200cm FFD.

Table 1: Densitometer Readings

Projection	FFD(cm)	Average Optical Density* (OD)
AP	100	1.15
AP	200	0.92
LAT	100	0.54
LAT	200	0.42

Average densitometer readings for radiographs performed at 100cm and 200cm FFD.

* An average of five readings from identical anatomical reference points.

Figure 3a. Photograph representing an anterior to posterior view of the phantom at an FFD of 100cm and 40 mAs.

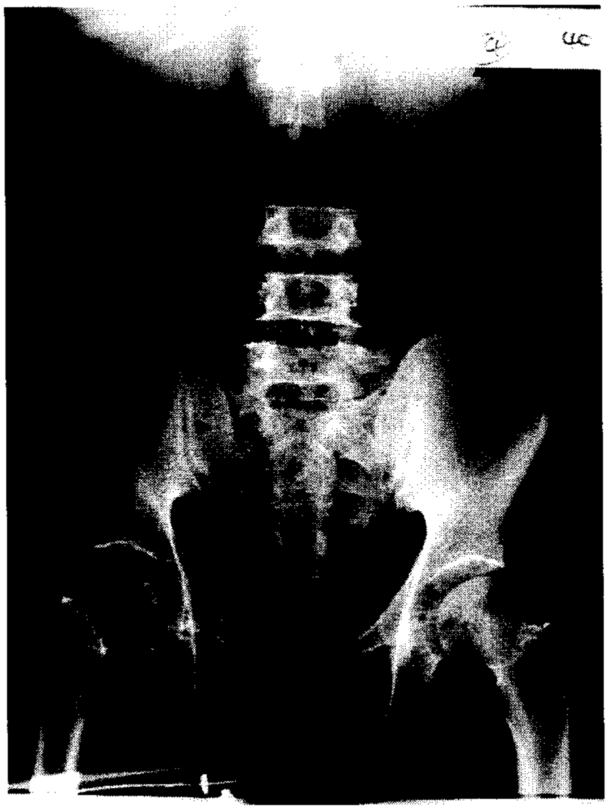


Figure 3b. Photograph representing an anterior to posterior view of the phantom at an FFD of 200cm and 160 mAs.

Testicular entrance doses were also reduced by utilising a 200cm FFD (table 2). For the AP 200cm FFD the testicular entrance dose has reduced by 30% (2.12mGy/ 3.11mGy X 100), while for the lateral a 70% (0.12mGy/ 0.04mGy X 100) reduction has taken place (table 2).

Table 2. Testicular entrance dose.

Projection	FFD(cm)	kVp	mAs	Entrance dose (mR)
AP	100	70	40	3.11mGy
AP	200	70	160	2.18mGy
LAT	100	90	64	0.12mGy
LAT	200	90	250	0.04mGy

Testicular entrance doses for lumbar-pelvic radiography using 100 cm and 200 cm FFD variations.

The same pattern of reduced entrance doses were further observed during FFD alterations for the central air dose (table 3). Further in all lateral views for both 100cm and 200cm FFDs the average readings observed were lower than those for the AP views.

Table 3: Central air doses.

Projection	FFD (cm)	kVp	mAs	Entrance dose (mR)
AP	100	70	40	2.06mGy
AP	200	70	160	1.73mGy
LAT	100	90	64	0.05mGy
LAT	200	90	250	0.04mGy

Central air doses for lumbar-pelvic radiography at 100 cm and 200 cm FFD.

DISCUSSION

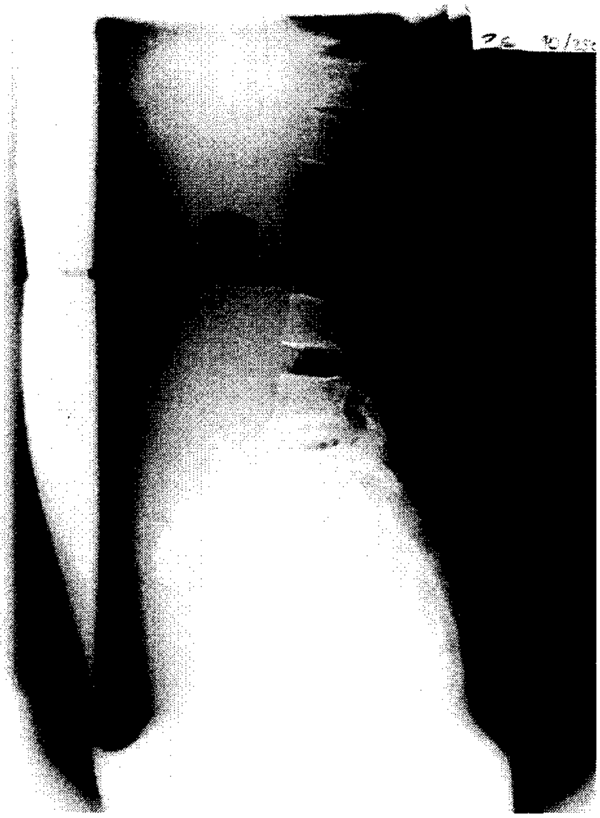
For AP lumbar-pelvic radiography, increasing FFD by a factor of two resulted in an approximately 30% decrease in entrance dose to the testes (table 2). This result was obtained using a constant 70 kVp and highly comparable optical densities.

A larger relative reduction in testicular entrance dose was obtained for lateral lumbar-pelvic radiography. At 100 cm FFD entrance doses of 0.12 mGy were obtained, while at 200 cm FFD only 0.04 mGy of radiation dose was measured (table 2). This constitutes a 70% reduction in entrance dose as compared with the use of shorter FFDs. While an entrance doses of 0.12 mGy and 0.04 mGy are both considered very small (table 2), with repeated radiography in a short time frame, the accumulated doses using larger FFDs will be of considerable difference.

The difference in percentage reduction in entrance doses from AP to lateral radiography can be explained by the beam quality measured in these projections. In the AP projection, primary radiation (of higher energy) is incident on the dosimeter and patient. In lateral lumbar-pelvic projections the testes receive secondary or scatter radiation (of lower energies) which has been produced by the

Figure 4a. Photograph representing a lateral view of the phantom at an FFD of 100cm and 64 mAs.

Figure 4b. Photograph representing a lateral view of the phantom at an FFD of 200cm and 250 mAs.



muscle and fat scattering medium of the overlying thigh, pelvis and testes tissue as well as scattering in the surrounding air. These results exemplify the effects of appropriate and accurate collimation practices during radiographic positioning.

Central air doses show a small reduction in patient entrance doses when going from 100 to 200 cm FFD (Table 3). When comparing central beam air doses to testicular doses a smaller reduction in dose at 200 cm FFD is noted. This can be attributed to the effect of beam geometry whereby divergence of the beam at the edges of a 35 x 43 cassette produces a non-homogenous exposure beam.

While this paper limits itself to the investigation of the effects of FFD variation to testicular dose. Further investigations will be conducted to quantify penumbra and measurement accuracy. It is generally understood that at larger FFDs penumbra decreases significantly and hence resolution increases.

CONCLUSIONS

With the steady increase in public and professional concern regarding the biological effects of ionising radiation, there is a need for both the Chiropractic and Radiography professions to improve imaging techniques for the lowering of patient radiation doses.

Using the male testes as the critical target organ, this study has shown that for both AP and lateral lumbo-pelvic radiography, the entrance dose to the testes has been significantly reduced when employing larger FFDs. For AP radiography a 30% testicular dose reduction is achievable while for lateral radiography 70% reduction in testicular dose was obtained. The results are consistent with the principles of the inverse square law but also demonstrate beam hardening effects on patient doses in radiology. That is, while increasing radiation exposures for 200 cm FFDs, the additional air gap of 100 cm will reduce patient dose in lumbar-pelvic radiography significantly by removing lower energy ionising radiation. These lower energy photons would otherwise produce additional skin (and testicular) dose to the patient.

The study suggests for the first time that an FFD of 200 cm, which is largely utilised by the chiropractic profession, is an efficient method of minimising radiation dose to patients.

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